FIVE YEAR RESEARCH PLAN

1990-1994

C-CORE

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INTRODUCTION

The Centre for Cold Ocean Resources Engineering is an independently funded research institute located at Memorial University of Newfoundland in St. John's. C-CORE is involved in solving engineering problems related to resource development in cold oceans. The Centre undertakes research in **ice engineering**, **remote sensing**, and **seabed geotechnics**; it develops collaborative programs with industry, government and universities; and C-CORE educates and trains engineers and scientists.

C-CORE works within the framework of a five-year research plan. Each year research achievements for the preceding year are reviewed by industry and government at the annual C-CORE Associates' Workshop; research work proposed for the upcoming year is also assessed. Minor adjustments are made annually to the research plan to reflect any significant changes in research priorities that are brought forward at the meeting. Two to three years after a research plan has been implemented, it is subjected to a major review at an Associates' Workshop to ensure that the Centre's research continues to be relevant to the offshore sector. This review results essentially in a new five year research plan that reflects the greatest research priorities identified by industry and government within the mandate of C-CORE.

The Associates are the financial supporters of C-CORE's research. They include representatives from both industry and government but are predominantly from industry. In addition to Associate representatives attending the Workshop, a number of other experts are invited from both government and industry to participate in the major review of the research plan. Following the Workshop, a draft research plan is drawn up by the management of C-CORE to reflect the priorities identified at the Workshop. The plan is then circulated to all participants for any additional input before it is completed. When all input has been obtained and is incorporated, the plan is submitted to the Research Program Advisory Committee and the Board of Governors for review and approval. Following the Board's approval of the programs, C-CORE is authorized to continue with the implementation of the Centre's research plan and to secure the funding required to achieve the objectives in the plan.

The first research plan which followed this process was put forward by C-CORE in 1984 and was approved for implementation in 1985; it was subjected to a major review by the Associates of the Centre in 1987. At that time, a new research plan emerged and this was again subjected to a detailed review in May of 1989. This revised five year research plan reflects the priorities that were established at the May 1989 Associates' Workshop. The research plan was approved for implementation at the meeting of the Board of Governors, November 1989.

C-CORE's research has traditionally been strongly oriented to the

field. This continues to be the case, although components of the research require strong support from the laboratories of the National Research Council Canada, Institute for Marine Dynamics, Faculty of Engineering and Applied Science of Memorial University and the Newfoundland and Labrador Institute of Fisheries and Marine Technology. The objective of the Centre's five year plan is to address problems identified as being important to the exploration and development of Canada's offshore resources with a specific target of improving cost effectiveness and safety. Major resources that are considered in the research plan are oil and gas, heavy minerals, and fisheries. The research programs also have an impact on transportation and communications. The Centre's research focuses primarily on the physical environment but C-CORE's expertise can also be made available to other groups involved with biological and oceanographic research. Practically all the Centre's research programs are now cooperative ventures with scientists and engineers from industry, government and other institutes.

In the new five-year plan for the years, 1990 through and including 1994, C-CORE has maintained its three specific thrusts of research. These are ice engineering, seabed geotechnics and remote sensing. Considerations related to the presence of ice in most of the waters within the exclusive economic zone of Canada remain important to all three research thrusts; however, the skills and capabilities developed within each group are now being applied to other areas of high research priority in many fields of industrial activity. For example, the very strong acoustic capabilities within the geophysical team of the Seabed Geotechnics Group are being applied to fisheries problems and to monitoring of structures. Another example is the application of the Ground Wave radar technology within the Remote Sensing Group to research related to environmental issues. These new research programs, which respond to a market pull, represent a broadening of the base of C-CORE activities but are still closely linked to the Centre's mandate to undertake research related to ocean resources as embraced by the research plan.

The research plan for each area of activity is described in the following sections. New initiatives or a change in emphasis that resulted from the May 1989 Associates Workshop are identified.

ICE ENGINEERING

The Calgary Workshop held in May of 1989 identified a number of technical issues which should be addressed for the development of Canadian offshore resources. The following is a summary of the issues discussed at the Workshop:

Reliable forecasting of iceberg movement;
Determination of iceberg shape;
Full scale studies of the impact of icebergs on structures plus associated risks;
The assembly of a database on icebergs, and descriptions of the iceberg operating environment;
On the east coast, field studies to verify icing models and the development of techniques to mitigate icing;
In the Beaufort Sea, better description of extreme ice forms;
Improved understanding of the effect of ice loading on structures;
Improved knowledge of oil spills in broken ice;
The urgent necessity to improve ice monitoring systems and to couple these systems with ice forecasting;
Better knowledge of currents and their impact on iceberg movement; and
Forecasting of local wind and currents.

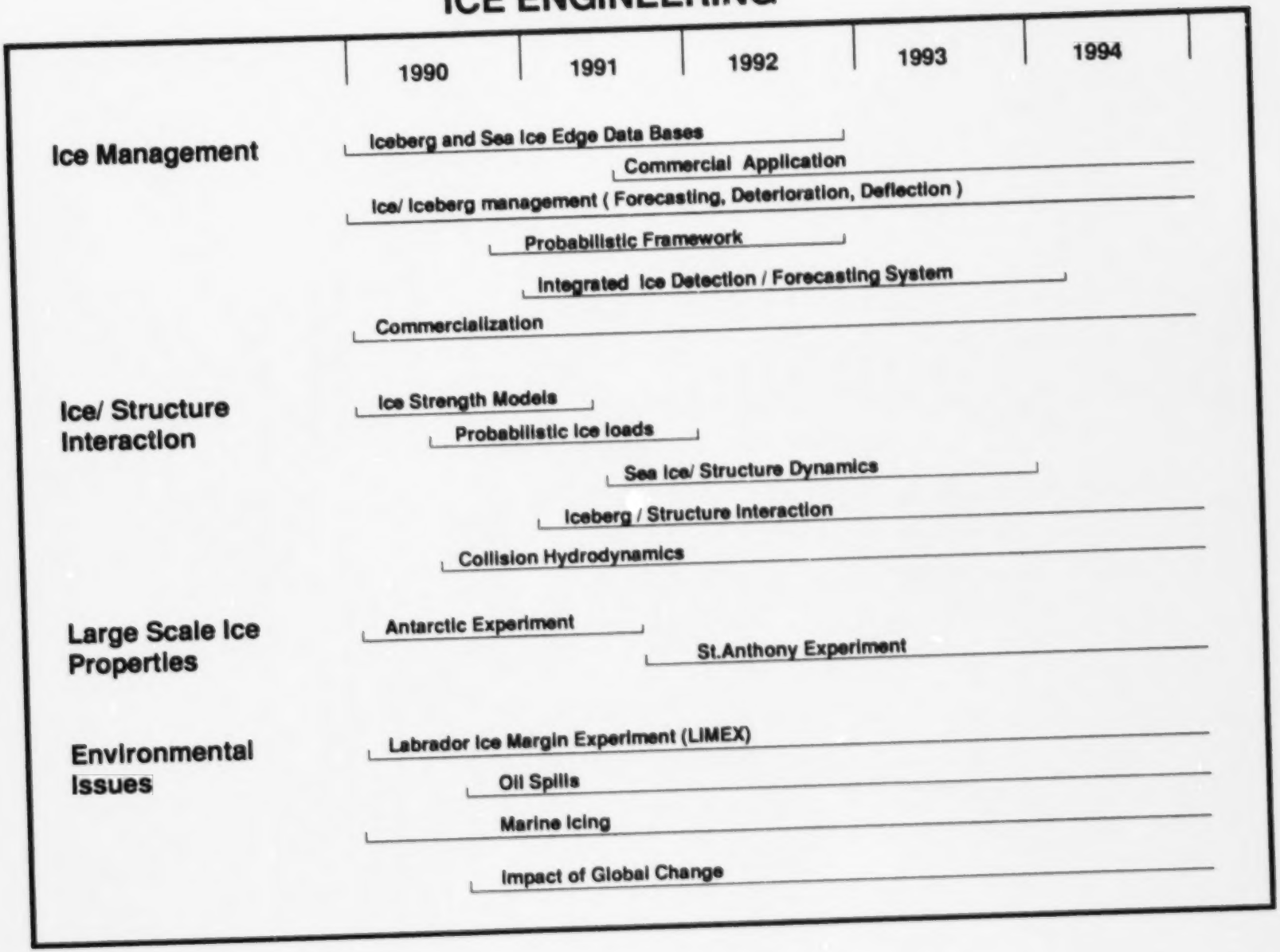
These priority technical issues have been taken into consideration in developing the Centre's five year plan in Ice Engineering. The need for improved forecasting of local conditions is not included in the plan since it is already well covered by other agencies. The Ice Engineering plan reflects the growth in expertise in ice/structure interaction which has developed from the previous five year plan. These activities included risk analyses and studies of structures interacting with pack ice and bergy bits. In response to priorities identified, C-CORE has increased its emphasis on ice management, specifically in relation to the organization and handling of ice data and ice forecasting. In addition, environmental issues have been given increased emphasis in the research plan. New initiatives include research related to problems that may arise as the result of an oil spill in pack ice, and the impact of global warming on northern operations. The plan has also been developed to complement the developments in satellite technology to improve the information which can be made available to those operating in the offshore environment.

ICE MANAGEMENT

Iceberg and Ice Edge Data Bases

Working closely with industry, government and consulting companies, and using standardized format, Ice/Iceberg data collected by several oil companies during drilling operations on the Grand Banks, Labrador Sea and Beaufort Sea will be organized and archived. This will be accomplished by a well documented, self explanatory computer database. It will be set up in a standard format compatible with those used by the Atmospheric Environment Service (AES), Canada Oil and Gas Lands Administration (COGLA) and

ICE ENGINEERING



other government agencies. The established data bases will ensure easy access and utilization by the potential users including the oil industry, shipping industry, research institutions, and Federal and Provincial Government agencies. The iceberg and ice edge data bases will be used to test forecasting models. They will also be used to provide statistics for probabilistic models of ice/structure interaction.

Ice Forecast System

Work is underway to develop and implement an Integrated Sea Ice/Iceberg Forecast System (IIFS) designed to assist offshore operations during the planned oil production on the Grand Banks. The system, to be completed by 1991, will include models for regional and site specific forecasting pertaining to iceberg trajectory, iceberg ensemble drift and sea ice edge drift. The long term objective will be to couple the system with the ice detection rig mounted radar system to provide an integrated ice management system for offshore operators.

IIFS will provide detailed site specific forecasts suited to clients' needs and will complement the Ice Data Integration and Analysis System (IDIAS), which is currently under development by the Atmospheric Environment Service (AES). When completed, the system will be transferred to industry for commercial application.

Ice Growth and Melting

To extend C-CORE's work in sea ice thermodynamics during the past year, investigations of the influence of growth, melting, and contact forces on the Labrador Ice Margin will be carried out. There are currently some unanswered questions about the importance of these factors in the advance and retreat of ice edges. In particular, the influence of wave induced melting must be determined. If the melting, growth, or contact forces are found to be important in comparison to other forces such as wind and currents, they must be incorporated into the ice edge drift model. At present, no other model incorporates these phenomena.

Iceberg Deterioration

The important mechanisms affecting the deterioration of Arctic icebergs have been modelled. This work will provide the basis for the development of an operational iceberg deterioration model. Investigations will also continue on modelling of calving and splitting of icebergs.

Iceberg Deflection

Research work will be undertaken to evaluate and enhance current iceberg deflection technology and demonstrate new techniques. The program will consist of small scale and full scale experiments.

Ice forecasting, iceberg detection capabilities, iceberg deflection, and platform ice tolerance will be integrated into a probabilistic framework for operation and design of floating systems in ice/iceberg areas. The relative importance of the potential tools and mitigative measures can then be assessed.

ICE-STRUCTURE INTERACTION

The objective of the program on ice-structure interaction is to better understand and predict the loads caused by sea-ice and icebergs on offshore and

Arctic structures. C-CORE will continue to work closely with the Faculty of Engineering and Applied Science at Memorial University of Newfoundland (MUN) and the Institute for Marine Dynamics (IMD) of the National Research Council of Canada to achieve this objective.

C-CORE is cooperating closely with the NSERC-Mobil Industrial Chair of Ocean Engineering at MUN on some aspects of this program starting with the fundamentals of ice as a brittle, viscoelastic, damaging material. The prediction of loads from the material properties is a formidable task and the subject of our continuing efforts. The new focus of our work is on analytical methods and mathematical models of ice strength. Probabilistic methods will be used to account for the presence of initial flaws in the ice as well as failure occurring in non-simultaneous zones. Acoustics provide a promising means to measure crack nucleation and propagation. The cyclic nature of ice fracture and clearing as well as the response of the structure will be studied to understand the dynamic character of ice loading. Numerical techniques, such as the finite-element method, backed up by experimental and field data, will be used to investigate these problems.

C-CORE will take the lead to apply this basic understanding of ice loading processes to several types of structures: 1) Beaufort drilling caissons with wide, vertical walls, 2) gravity based structures with triangular wedge ice bumpers and 3) moored semi-submersibles. For types 1) and 3) structures, dynamics are quite important whereas for type 2), the action of triangular indentors against icebergs is of interest. Results of this work will apply as well to bridge piers and wharves in ice invaded regions.

The hydrodynamics of the collision is also an important aspect of the problem. For example, model tests performed by C-CORE show that wave-diffraction from the columns of a semi-submersible can have a significant effect in deflecting oncoming small icebergs. An upcoming full scale iceberg impact test will also give some indication of hydrodynamic effects due to the proximity of a large structure. A systematic study will require the use of the wave tanks at MUN and IMD and close cooperation between our organizations.

The random nature of ice loads extends beyond the fundamental processes of ice failure. Randomness also characterizes the occurrence, the velocity and the size of ice masses. The reliability of detection and avoidance methods also affects operations and expected loads. C-CORE will continue to develop a probabilistic framework that will draw on information from systems developed for ice management. Using probabilistic models, C-CORE will identify the data and knowledge gaps which have the largest effect on the probabilistic ice loads. This information is extremely valuable for the codes for offshore platforms.

LARGE SCALE ICE PROPERTIES

Actual ice impacts involve contact areas of 10's to 100's of square metres, or 1000 to 10,000 times larger than most available experimental data. C-CORE is planning to make some measurements in this most important data gap. Building on model scale towing tank tests, C-CORE is gearing up for a full scale (but small)

iceberg impact test in Antarctica. The test will be performed in collaboration with the French Polar Expeditions at their Antarctic base in Terre Adelie. Depending on the results of this test, further, more ambitious tests are planned at the same location or, closer to home, near St. Anthony, Nfld. Thanks to the logistical support from the French, the Antarctic tests will provide valuable data as well as economical pilot tests for St. Anthony. The St. Anthony site is particularly promising due to its accessibility, water depth, iceberg population and steep cliffs.

ENVIRONMENTAL ISSUES

Labrador Ice Margin Experiment LIMEX

The ice engineering objectives stated above necessitate a solid knowledge of the offshore environment and an understanding how future resource developments are going to affect that environment. The Centre's ice research program includes several more basic studies addressing fundamental environmental issues.

The present offshore hydrocarbon activity and the winter deep sea fishery are conducted near the sea ice margin. In 1984, C-CORE researchers promoted a regional scale experiment to investigate the processes that dictate the severity and the extent of the ice cover. The Labrador Ice Margin Experiments (LIMEX) have emerged as a multi-organization cooperative venture focused on using new developments in remote sensing to aid offshore exploitation in the cold ocean environment. The RADARSAT Project Office acts as lead agency and the venture proceeds with funding and other support derived from governmental departmental budgets. The Centre has participated from the beginning, making its expertise in ice conditions, ice strength, and ice motion available to the experiment. The goal of this research is to improve the capabilities for ice management and for safer and more cost effective ice engineering.

The LIMEX experiments are now an integral part of the ice monitoring validation programs of two future radar remote sensing satellites, ERS-1 and RADARSAT. We benefit by our participation in this series of experiments through a technology transfer of advances in remote sensing to our research staff. We anticipate that RADARSAT will make a significant contribution in the detection of ocean and ice conditions. When the satellites are operational, they will provide all weather coverage at three day intervals through the full ice season. The regular satellite imagery will aid ice forecasting and sea ice management. The Centre plans to participate in the series of LIMEX projects that are scheduled through to the launch and implementation of the RADARSAT data stream in 1995/1996.

Marine Icing

The Centre's marine icing program was another environmental topic initiated in 1989. Colleagues from industry, government, and universities have agreed to sit on a technical advisory committee to help the Centre formulate its research strategy. Committee members felt that this new initiative was timely. Changes in the way the deep sea fishery is conducted are imminent. More service vessels will be at sea in all weather conditions when offshore hydrocarbon production begins. Some of the projected changes will

increase the risk of accident and loss due to marine icing. The committee recommends that C-CORE work on advancing the physics of natural spray icing and developing cost effective countermeasures.

Environmental Protection

Events and public attention during the past year underscore that the protection of the marine environment will continue to be a high priority in offshore development. While the emphasis must be directed at prevention, the proficiency for clean up must also be improved. Advances in cold ocean science and better engineering will lower the risk of accidents and minimize the release of contaminants into the environment. Several new initiatives will increase C-CORE's contribution to the understanding and the protection of our marine environment. Investigations of the behaviour of oil in broken ice fields such as the Labrador ice margin are planned in collaboration with government and industry. This program will include theoretical analysis, laboratory experiments, field studies, and numerical modelling. Results of such research will help the protection agencies mitigate the damage from a spill by improving clean up techniques.

Impact of Global Change

Any global climatic change will have an impact on how northern resource development will be conducted. The Centre has been requested to investigate the consequences of these changes to offshore exploitation. Associated research topics like the LIMEX investigation of wave action on ice, the ice growth and melting, and the modelling capability of the sea ice database and forecast system provide some of the basic tools required to conduct such a study. The objective would be to predict how projected changes in the climate may affect the sea ice coverage and as a consequence, what changes in engineering and operations will have to be implemented to deal with the envisaged changes of the ice environment.

SEABED GEOTECHNICS

At the 1989 Calgary Workshop, a number of technical issues in Seabed Geotechnics were identified as priorities which need to be addressed. These are as follows:

A reduction in the cost of geotechnical seafloor investigations;
More cost effective methods of collecting information on sub-bottom soils;
Improved methods to identify hydrates and predict their existence;
More information on the distribution of scours, especially on the east coast, to assist in the protection of wellheads and pipelines;
A better understanding of the interaction between ice islands and the soil, pipeline landfalls and regions of unstable coastlines; and
In the environmental field, the movement of unconsolidated bottom sediments in the case of an oil spill or blowout.

These priority issues have been taken into account in the Centre's proposed five year plan utilizing the growth in the Centre's expertise in geophysics and acoustics. Areas of new research include environmental monitoring/assessment, bio-acoustics, artificial intelligence, geographical information processing and field applications of the ASI (Acoustic Sub-seabed Interrogator) concept. Steps are also being taken to establish directed studies in non-linear acoustics for long distance underwater communications.

MARINE GEOPHYSICS

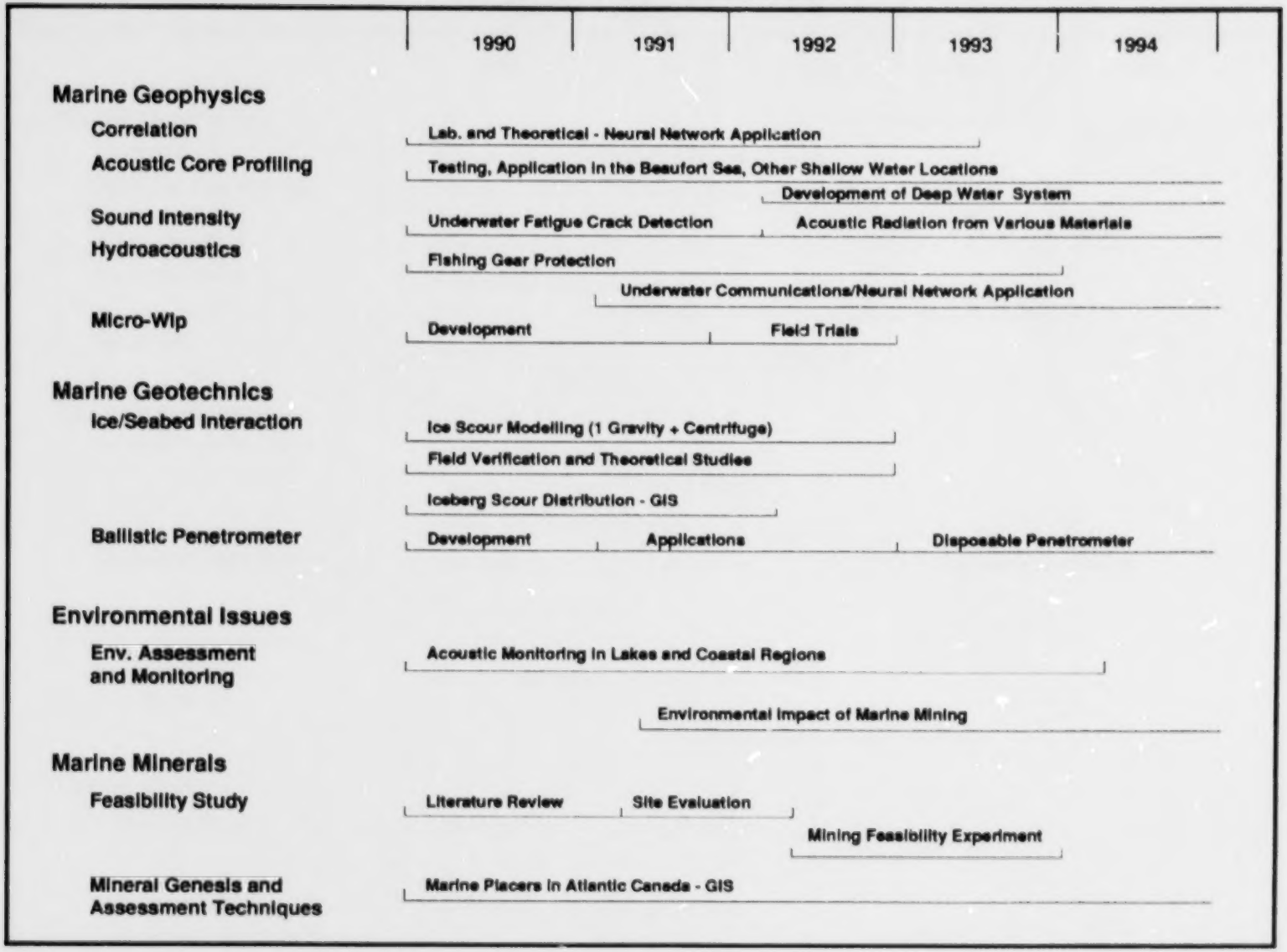
Geophysical/Geotechnical Sediment Property Correlation

A fundamental and continuing research focus will be to establish relationships between acoustic properties (velocities and attenuation) and geotechnical properties (density, porosity, shear modulus, and damping) of selected sediments in support of the ASI and its associated developments. This research includes investigation of acoustic propagation models. A program is being designed to investigate compressional and shear wave data while varying effective stress. This study will provide information on geophysical property gradients with depth. In conjunction with the laboratory work, deployment of the acoustic core profiling technology at ground-truthed sites will provide full-scale comparisons for correlation purposes.

Acoustic Core Profiling

A shallow water (50 metre water depth) Conventional Optimization Acoustic Sub-seabed Interrogator (CO-ASI), based on the ASI concept, has been designed and fabricated. It consists of an advanced design, multi-tip sparker source and directional receivers mounted on a 5m diameter platform from which high resolution acoustic velocity and attenuation information can be acquired. The program focus is now on the signal

SEABED GEOTECHNICS



processing to allow the CO-ASI to perform layer-by-layer interrogations to a depth of 50m into the seabed. The next phase will concentrate on relating the resulting acoustic responses to physical and geotechnical soil properties as derived from the C-CORE laboratory study and field ground-truthing. The field work will also be directed towards evaluating the ability of high resolution spot profiles to enhance the confidence, reliability and cost-effectiveness of geotechnical investigations. Developments during the next five years of the acoustic core profiling technology will include application in the Beaufort Sea and Norwegian waters. A deep water prototype (400 metre water depth) is proposed. It is also proposed to use the acoustic core technology to assist in the identification of hydrates in the seabed to verify current algorithms for hydrate indicators.

Sound Intensity Techniques to Study Fatigue in Offshore Structures

The program is directed towards development of techniques using acoustic intensity scanning for the remotely sensed, non-destructive assessment of fatigue and crack growth in offshore structures. The planned investigations will improve our understanding of the physics of acoustic energy flow as generated by vibrations. A broader range of materials and structures will be tested; these tests will encompass emission mapping of ice, cement and composite polymers. Field applications such as embedding an intensity array into an ice sheet are being proposed.

Neural Networks

Studies in neural network theory are proceeding towards the application of learning algorithms for offshore structural monitoring and intelligent geophysical mapping. Neurocomputers can be utilized to solve complex problems without well-defined algorithms and to process "blurry" data. Given the empirical nature of geophysical/geotechnical correlations, neural computing will be pertinent to the final processing stage for the acoustic core product. Future neural network initiatives include concentrating on the solution of problems for industrial applications using specialized dedicated nets.

MICRO-WIP Project

Prospecting for placer deposits and appraising their economic worth will require the development of new methods. A MICRO-WIP system has been developed to measure induced polarization response of sediments which contain small concentrations of metallic minerals. The existing system developed by an industrial partner operates only in fresh water. We propose to continue the development of the MICRO-WIP system for marine applications and it may also assist in the identification of hydrates in the soil. This will help to determine the limits of potential placers. We also propose a study of sampling methods emphasising the rate of recovery of heavy minerals in drilling using different techniques. This would lead to trials with conventional drilling systems in synthetic soils, and studies of ways to improve sampling efficiencies.

MARINE GEOTECHNICS

Ice/Seabed Interaction

Ice scour research will remain a significant area of research. High priority projects involve the interaction of

icebergs, sea ice, ice islands and pressure ridge keels with the seabed soil. The mechanics of ice/seabed interaction based on field studies in Manitoba will be expanded to better delineate and analyze the disturbances noted below the ice keel encounter. Field programs in ice invaded tidal flats at spring breakup will acquire additional information on the ice/seabed interactions.

Iceberg scour physical modelling is currently emphasized, with the results directed towards theoretical prediction models. The acoustic core profiling technology will be employed for studies on modern scours. A cooperative program is being formulated between C-CORE and the Norwegian oil/gas industry to study geotechnical aspects of ice/seabed interaction.

Iceberg Scour Distribution

Our present research in Geographical Information Systems involves the use of off-the-shelf packages to analyze iceberg scour statistics. Statistical distribution of physical dimensions of iceberg scours combined with seabed soils and wave/current information should provide insight into average iceberg size and frequency of grounding events along the eastern Canadian Continental Shelf.

Ballistic Penetrometer Development

The ballistic penetrometer technology is addressing a requirement for rapid (and cost-effective) measurement of geotechnical seabed properties for pipeline and cable route surveys as well as for investigations of the deep ocean. Development is continuing on an instrumented ballistic penetrometer for geotechnical soil characterization. At present the device is capable of measuring acceleration and nose and sleeve resistance. The next step will be to engineer pore pressure transducers and an inclinometer. The field programs planned are to correlate penetration data with ground-truth information. Future development plans focus on the engineering of a disposable, high velocity device.

Centrifuge Modelling

Centrifuge modelling is an ideal means of undertaking certain types of geotechnical and ice engineering research. In particular, events which are unpredictable, such as iceberg grounding/impacts, are amenable to this type of modelling. C-CORE is involved in several proposals to perform centrifuge tests at the Cambridge University facility. In addition, C-CORE has taken the lead in a proposal to fund a large geotechnical centrifuge centre for St. John's. This centre will be dedicated to cold regions research. The centrifuge centre will be on the University campus adjacent to the C-CORE Building. It is intended that the facility be fully self-sufficient.

The Centrifuge Centre will be able to model long-term cold events as well as the traditional type of event modelled on centrifuges. To date, this proposal has received substantial encouragement from both industry and government. A proposal to perform a detailed market study has been submitted to the provincial government. The decision whether or not to continue with this initiative will be based upon the results of the market analysis.

ENVIRONMENTAL ISSUES

Environmental Assessment and Monitoring

New markets for marine geoscientific research at C-CORE have been identified as a result of increasingly apparent marine environmental quality issues. One aspect involves the evaluation of acoustic monitoring systems for sediment transport in the St. Lawrence and Great Lakes. Existing systems do not have sufficient stability or resolution to achieve the desired results. We are designing a new generation of intelligent profilers based on non-linear acoustics and neural networks to provide millimetre scale resolution of the bathymetry and highly detailed stratigraphy of the upper metre of soil. The system will have applications in marine archaeology, harbour construction and dredging, as well as *in-situ* monitoring. Ultimately, the use of these remote sensing geophysical tools will improve interpretations of core and sample-derived information by providing more exact data on the temporal and spatial variability of the materials under investigation.

Geographical Information Systems (GIS) are used routinely to handle the large volumes of multivariate data associated with satellite image analysis and soils mapping. There is considerable potential to develop and apply systems which are optimised for marine geoscientific data analysis requirements.

Additional applications in GIS will focus on modelling dynamic processes in the ocean environment. These applications include the distribution of heavy minerals for placer studies and the distribution of sediment chemical data for modelling industrial waste dispersion in the ocean environment.

Environmental Impact of Marine Mining

As part of a larger program to evaluate the feasibility of marine mining in Newfoundland, the Centre proposes to develop and test a framework for environmental impact assessment of a pilot-scale marine mineral extraction experiment. The first step is to review the present literature on dredging impacts coupled with a study of the environmental program in place in support of a commercial marine gold mining operation in Norton Sound, Alaska. As exploration for a suitable extraction site proceeds, baseline environmental information will be collected at potential sites. The final choise of sites will depend in part on the ability to acquire information pertinent to environmental impact assessment. During and for two years following the extraction experiment, the water column, the seabed and the associated biota will be monitored to allow an accurate appraisal of the environmental costs of marine mining at a specific location on the Newfoundland shelf.

MARINE MINING

Feasibility Study

Interest in mining hard minerals in Canadian waters has raised significant questions about both the economic potential and the possible environmental impacts of such ventures. In order to investigate these questions, a study is proposed to determine the feasibility of small-scale placer mining operations in Newfoundland.

The Centre will investigate

methods to delineate mineral concentrations in the offshore. Geophysical, geological, and geochemical studies will take place to evaluate economic potential in several locations with high mineral potential. The final stage of the project will consist of an experiment to determine the feasibility of marine mining via a pilot-scale mineral dredging operation. Preliminary investigations suggest that a clam-shell dredge mounted on a barge will provide a reasonable means of extracting the ore. It is anticipated that processing facilities will be housed on the barge and material will be returned to the seafloor after concentration of the heavy mineral fraction. This scenario will effectively emulate an actual mining operation.

Mineral Genesis and Assessment Techniques

Current mining industry perception is that marine mineral placer exploration in Canadian waters is too risky to justify the effort involved in overcoming potential environmental impacts. In order to decrease the risk, the Centre will continue research within the framework of previous studies such as the marine placer classification scheme and techniques for placer assessment developed at C-CORE. The research will concentrate on a few of the most attractive areas in Newfoundland to assess the models developed at C-CORE for marine placer genesis and to experiment with new and existing exploration and assessment technologies. The primary goals of the program will be the refinement of the classification scheme and depositional models for marine placer assessment, the application of sediment transport models and geostatistical techniques to quantify mineral concentrating mechanisms and an investigation of acoustic and electrical signatures of marine placers both in the laboratory and in situ. Electrical measurements will consist of resistivity and induced polarization responses as acquired by the microwip development project.

REMOTE SENSING

The Ground Wave radar program is the most mature of the Centre's research areas. Fundamental research, which began over ten years ago, has been applied to priority issues in close collaboration with industry and government. The transfer of the Ground Wave radar technology for commercial applications is currently under way with the transfer of the technology for the shore based surveillance system to Northern Radar Systems Limited (NRSL). The Group's research for the next five years will focus on ice and iceberg hazard detection systems which can be placed on structures and vessels. The technical issues identified as priorities at the 1989 Calgary workshop emphasized that Ground Wave radar systems developed at C-CORE can make a significant contribution to ice management, particularly on the east cost, and to safety and evacuation for all offshore operations.

The technical issues which were identified as priorities in the Remote Sensing discussions at the workshop were:

Reliable forecasting of ice hazards;
Cost effective tools to detect and track drifting ice and iceberg hazards to complement other existing techniques;
Improved detection of smaller sizes of icebergs, bergy bits and growlers;
An urgent requirement for a vessel mounted radar system with real time information on the ice and ocean environment; and
In environmental issues, systems which can be deployed rapidly and can provide real time information on currents and sea state.

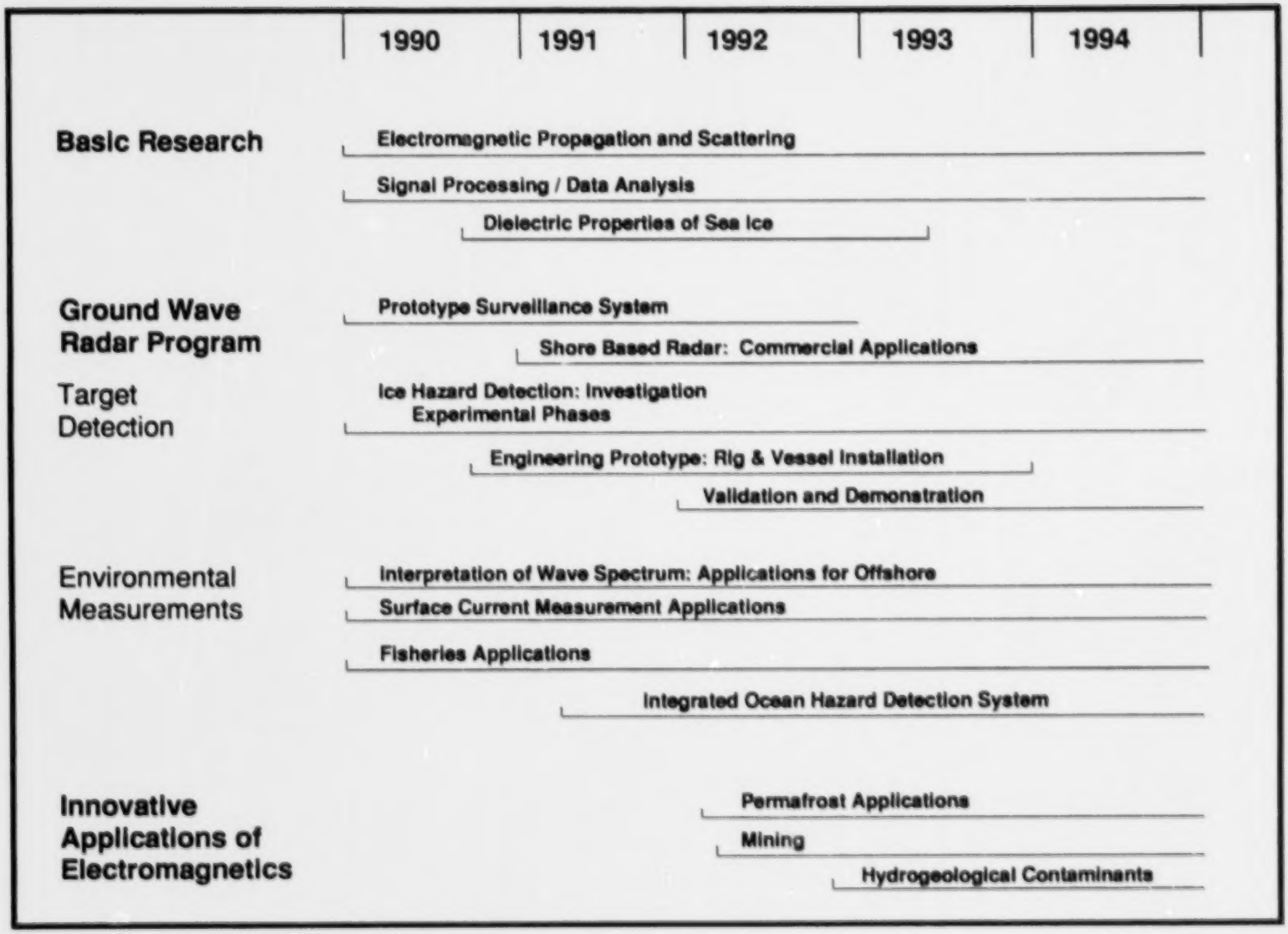
The Workshop also identified the need to be able to discriminate between multi-year ice and icebergs incorporated into first year sea ice cover. It is unlikely that Ground Wave radar can make a significant contribution to this problem; an initial study will be conducted to indicate the probability of success of undertaking a program to address the problem.

BASIC RESEARCH

The Remote Sensing Group will continue its basic research on the physics of the complex electromagnetic scattering phenomenon at ground wave frequencies. The signal processing research activity is directed to processing and interpreting Ground Wave radar (GWR) signals, with particular emphasis on the Centre's ice hazard and target detection programs. New research is planned which will investigate the dielectric and backscattering properties of young sea ice at GHz frequencies. This research will assist in ice typing with satellite synthetic aperture radar (SAR) systems.

There have been significant advances in the modelling of electromagnetic (EM) propagation and scatter. New analytical models have been developed to predict radar cross sections for ice hazards, sea clutter, surface vessels and low altitude airborne targets. The investigations into scattering from the ocean surface (ocean clutter) are ongoing; the increased understanding of the scattering process will ultimately determine the detectability of targets in

REMOTE SENSING



the presence of clutter, and the ability to perform ocean environmental measurements with GWR sensors. An investigation into the feasibility of distinguishing different types of ice hazards by ground wave techniques, for example, icebergs in total ice cover, will be considered.

The emphasis of the signal processing and data analysis program is to investigate the fundamental characteristics of the received echo signals and to develop appropriate methods of processing and interpreting the various components of the signal. The primary focus is to develop new methods of enhancing target signals in the presence of ocean clutter and noise, ocean clutter reduction techniques, target tracking techniques, adaptive filtering and time domain processing. The advanced signal processing methods developed under this program may also have applications in other related fields.

Investigations into the effect of sea ice surface properties on radar backscatter will be initiated. The application of spaceborne SAR systems for ice detection and classification is currently limited by the poor understanding of the relationships between ice surface properties and radar backscatter. Detailed time series of the physical and dielectric properties of evolving first-year ice covers will greatly aid in the development of ice typing algorithms.

GROUND WAVE RADAR

Target Detection

Ground Wave radar technology will add to the available suite of remote sensing systems to detect ice cover, icebergs, vessels and low flying targets. Two types of systems are under development: a long range shore based system and a short range rig or vessel system.

The shore based facility, at Cape Race Newfoundland, is being constructed by a private company, Northern Radar Systems Limited (NRSL), and will become operational by mid-1990. C-CORE is the main subcontractor, supplying the GWR expertise, to develop the radar hardware/software system. The prototype radar is a multi-purpose system capable of monitoring vessel traffic, detecting and tracking icebergs/ice edges and collecting ocean wave and surface current measurements out to the limit of the Canadian Exclusive Economic Zone. C-CORE will participate in future research and development opportunities based on the capabilities of the prototype system. NRSL will develop commercial applications of the land based GWR technology for world wide markets.

The development of an offshore structure or vessel based ice hazard detection Ground Wave radar system will result in a reliable, dedicated, hazard warning system to aid in safe offshore operation. Fundamental antenna aperture and signal processing problems encountered when attempting to operate from the limited and congested space of an offshore rig or vessel will be addressed in developing this technology. An additional problem arises from the fact that the moving radar platform induces additional contamination into the GWR signals. Research has identified new methods for contending with these additional issues.

Many system innovations will be

required to develop engineering solutions to these problems. It is expected that an initial prototype system will be developed and ready for testing by 1991.

Environmental Measurements

Significant advances have been made in the application of Ground Wave radar to measure ocean wave spectra. The basic EM research has been applied to yield new algorithms to interpret and estimate the wave height spectrum from a single antenna return and wave directional spectra from two spatially separated antennas. Work is now proceeding to formulate the scattering equations and to develop the interpretative techniques to estimate ocean wave conditions for broad beam antennae. Broad beam antennae will be applied to portable coastal radars and to radars on structures and vessels. The wave measurement capability of the radar will add to its present surface current mapping role where radar is used as a tool for conducting oceanographic studies.

The surface current measurement role for the radar is at a mature state. The hardware will be re-engineered to incorporate the major advances in radio receivers, computing and digital signal processing that have taken place since the original Coastal Ocean Dynamics Application Radar (CODAR) system was introduced. The expertise gained through the development of the NRSL prototype GWR system will enable the CODAR system development to proceed in a very cost effective manner. The Centre will continue to explore commercial application for ocean surface current and ocean wave remote sensing techniques. The plan is to transfer this role to the private sector as the markets for the ocean surface current and ocean wave measurements become established. The system has been proposed to aid search and rescue missions, oil spill tracking and fisheries research studies.

Innovative Applications of Electromagnetics and Signal Processing

The analytical and signal processing techniques which emerge from the Ground Wave radar program will be applied to other fields. The potential of using electromagnetics for geophysical prospecting and remote testing of geophysical properties of seabed and onshore exploration sites will be investigated in conjunction with the Seabed Group.